

**A Study of the Rare Decays  $B^0 \rightarrow D_s^{(*)+} \pi^-$  and  $B^0 \rightarrow D_s^{(*)-} K^+$** The *BABAR* Collaboration

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**Abstract**

We report on the evidence for the decays  $B^0 \rightarrow D_s^+ \pi^-$  and  $B^0 \rightarrow D_s^- K^+$  and the results of a search for the decays  $B^0 \rightarrow D_s^{*+} \pi^-$  and  $B^0 \rightarrow D_s^{*-} K^+$  from a sample of 84 million  $\Upsilon(4S)$  decays into  $B$  meson pairs collected with the *BABAR* detector at the PEP II asymmetric-energy  $e^+e^-$  collider. The measured  $B^0 \rightarrow D_s^+ \pi^-$  yield has a probability of less than  $10^{-3}$  to be a fluctuation of the background and we measure the branching fraction  $\mathcal{B}(B^0 \rightarrow D_s^+ \pi^-) = (3.2 \pm 0.9 \text{ (stat.)} \pm 1.0 \text{ (syst.)}) \times 10^{-5}$ . The measured  $B^0 \rightarrow D_s^- K^+$  yield has a probability of less than  $5 \times 10^{-4}$  to be a fluctuation of the background and we measure the branching fraction  $\mathcal{B}(B^0 \rightarrow D_s^- K^+) = (3.2 \pm 1.0 \text{ (stat.)} \pm 1.0 \text{ (syst.)}) \times 10^{-5}$ . We also set 90% C.L. limits  $\mathcal{B}(B^0 \rightarrow D_s^{*+} \pi^-) < 4.1 \times 10^{-5}$  and  $\mathcal{B}(B^0 \rightarrow D_s^{*-} K^+) < 2.5 \times 10^{-5}$ . All results are preliminary.

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The measurement of the  $CP$ -violating phase of the Cabibbo-Kobayashi-Maskawa (CKM) matrix [1] is an important part of the present scientific program in particle physics.  $CP$  violation manifests itself as a non-zero area of the unitarity triangle [2]. While it is sufficient to measure one of the angles to demonstrate the existence of  $CP$  violation, the unitarity triangle needs to be overconstrained by experimental measurements, in order to demonstrate that the CKM mechanism is the correct explanation of this phenomenon. Several theoretically clean measurements of the angle  $\beta$  exist [3], but there is no such measurement of the two other angles  $\alpha$  and  $\gamma$ . A theoretically clean measurement of  $\sin(2\beta + \gamma)$  can be obtained from the study of the time evolution of the  $B^0 \rightarrow D^{(*)-} \pi^+$  [4] decays, of which a large sample is already available at the B-factories, and of the corresponding Cabibbo suppressed mode  $B^0 \rightarrow D^{(*)+} \pi^-$  [5]. This measurement requires the knowledge of the ratio between the decay amplitudes  $R_\lambda^{(*)} = |A(B^0 \rightarrow D^{(*)+} \pi^-) / A(B^0 \rightarrow D^{(*)-} \pi^+)|$ . Unfortunately the measurement of  $|A(B^0 \rightarrow D^{(*)+} \pi^-)|$  via the measurement of  $\mathcal{B}(B^0 \rightarrow D^{(*)+} \pi^-)$  is not possible with the currently available data sample due to the presence of the copious background from  $\bar{B}^0 \rightarrow D^{(*)+} \pi^-$ . However, we can measure  $\mathcal{B}(B^0 \rightarrow D_s^{(*)+} \pi^-)$  and relate it to  $R_\lambda^{(*)}$  using SU(3) symmetry:  $R_\lambda^{(*)2} \propto \frac{\mathcal{B}(B^0 \rightarrow D_s^{(*)+} \pi^-)}{\mathcal{B}(\bar{B}^0 \rightarrow D^{(*)-} \pi^+)}$ , where the proportionality constant is, to first approximation, the ratio of the  $D_s^{(*)+}$  and the  $D^{(*)+}$  decay constants [5]. The decays  $B^0 \rightarrow D_s^{(*)+} \pi^-$  have also been proposed to be used for the measurement of  $|V_{ub}/V_{cb}|$  [6].

The decays  $B^0 \rightarrow D_s^{(*)-} K^+$  are a probe of the dynamics in  $B$  decays because they are expected to proceed mainly via a W-exchange diagram, not observed so far. In addition, these modes can be used to investigate the role of final state rescattering since its presence can substantially increase the expected rates [7]. In this letter we present measurements of the branching fractions for the decays  $B^0 \rightarrow D_s^{(*)+} \pi^-$  and  $B^0 \rightarrow D_s^{(*)-} K^+$ .

This analysis uses a sample of 84 million  $\Upsilon(4S)$  decays into  $B\bar{B}$  pairs collected in the years 1999-2002 with the *BABAR* detector at the PEP-II asymmetric-energy  $B$ -factory [8]. Since the *BABAR* detector is described in detail elsewhere [9], only the components of the detector crucial to this analysis are summarized below. Charged particle tracking is provided by a five-layer silicon vertex tracker (SVT) and a 40-layer drift chamber (DCH). For charged-particle identification, ionization energy loss ( $dE/dx$ ) in the DCH and SVT, and Cherenkov radiation detected in a ring-imaging device are used. Photons are identified and measured using the electromagnetic calorimeter, which comprises 6580 thallium-doped CsI crystals. These systems are mounted inside a 1.5 T solenoidal superconducting magnet. We use the GEANT [10] software to simulate interactions of particles traversing the *BABAR* detector, taking into account the varying detector conditions and beam backgrounds.

We select events with a minimum of three reconstructed charged tracks and a total measured energy greater than 4.5 GeV as determined using all charged tracks and neutral clusters with energy above 30 MeV. In order to reject continuum background, the ratio of the second and zeroth order Fox-Wolfman moments [11] must be less than 0.5.

So far, only upper limits on the modes studied in this letter exist [13]. Therefore the selection criteria are optimized to maximize the ratio of signal efficiency over the square-root of the expected number of background events.

The  $D_s^+$  mesons are reconstructed in the modes  $D_s^+ \rightarrow \phi \pi^+$ ,  $K_s^0 K^+$  and  $\bar{K}^{*0} K^+$ , with  $\phi \rightarrow K^+ K^-$ ,  $K_s^0 \rightarrow \pi^+ \pi^-$  and  $\bar{K}^{*0} \rightarrow K^- \pi^+$ . The  $K_s^0$  candidates are reconstructed from two oppositely-charged tracks with an invariant mass  $493 < M_{\pi^+ \pi^-} < 501$  MeV/ $c^2$ . All other tracks are required to originate from a vertex consistent with the  $e^+ e^-$  interaction point. In order to identify charged kaons, two selections are used: a pion veto with an efficiency of 95% for kaons and a 20% pion misidentification,



and a tight kaon selection with an efficiency of 85% and 5% pion misidentification probability. If not otherwise specified, the pion veto is always adopted. The  $\phi$  candidates are reconstructed from two oppositely-charged kaons with an invariant mass  $1009 < M_{K^+K^-} < 1029 \text{ MeV}/c^2$ . The  $\bar{K}^{*0}$  candidates are constructed from the  $K^-$  and a  $\pi^+$  candidates and are required to have an invariant mass in the range  $856 < M_{K^-\pi^+} < 936 \text{ MeV}/c^2$ . The polarizations of the  $\bar{K}^{*0}(\phi)$  mesons in the  $D_s^+$  decays are also utilized to reject backgrounds through the use of the helicity angle  $\theta_H$ , defined as the angle between one of the decay products of the  $\bar{K}^{*0}(\phi)$  and the direction of flight of the meson itself, in the meson rest frame. Background events are distributed uniformly in  $\cos\theta_H$  since they originate from random combinations, while signal events are distributed as  $\cos^2\theta_H$ . The  $\bar{K}^{*0}$  candidates are therefore required to have  $|\cos\theta_H| > 0.4$ , while for the  $\phi$  candidates we require  $|\cos\theta_H| > 0.5$ . In order to reject background from  $D^+ \rightarrow K_S^0 \pi^+$  or  $\bar{K}^{*0} \pi^+$ , the  $K^+$  in the reconstruction of  $D_s^+ \rightarrow K_S^0 K^+$  or  $\bar{K}^{*0} K^+$  is required to pass the tight kaon identification criteria introduced above. Finally, the  $D_s^+$  candidates are required to have an invariant mass within  $10 \text{ MeV}/c^2$  of the nominal mass [12].

We reconstruct  $D_s^{*+}$  candidates in the mode  $D_s^{*+} \rightarrow D_s^+ \gamma$ , by combining  $D_s^+$  and photon candidates. Photons that form a  $\pi^0$  candidate, with  $122 < M_{\gamma\gamma} < 147 \text{ MeV}/c^2$ , in combination with any other photon with energy greater than 70 MeV are rejected. The mass difference between the  $D_s^{*+}$  and the  $D_s^+$  candidate is required to be within  $14 \text{ MeV}/c^2$  of the nominal value [12].

We combine  $D_s^+$  or  $D_s^{*+}$  candidates with a track of opposite charge to form  $B^0 \rightarrow D_s^{(*)-} K^+$  or  $B^0 \rightarrow D_s^{(*)+} \pi^-$  candidates depending on whether they pass the tight kaon selection criteria. In order to reject events where the  $D_s^+$  comes from a  $B$  candidate and the pion or kaon from the other  $B$ , we require the two candidates to have a probability greater than 0.25% of originating from a common vertex. The remaining background is predominantly combinatorial in nature and arises from continuum  $q\bar{q}$  production. In order to suppress it using the event topology, we compute the angle ( $\theta_T$ ) between the thrust axis of the  $B$  meson decay product candidates and the thrust axis of all the other particles in the event. In the center-of-mass frame (c.m.),  $B\bar{B}$  pairs are produced approximately at rest and produce a uniform  $\cos\theta_T$  distribution. In contrast,  $q\bar{q}$  pairs are produced back-to-back in the c.m. frame, which results in a  $|\cos\theta_T|$  distribution peaking at 1. Depending on the background level of each mode,  $|\cos\theta_T|$  is required to be smaller than a value which ranges between 0.7 and 0.8. We further suppress backgrounds using a Fisher discriminant  $\mathcal{F}$  constructed from the scalar sum of the c.m. momenta of all tracks and photons (excluding the  $B$  candidate decay products) flowing into 9 concentric cones centered on the thrust axis of the  $B$  candidate [14]. The more spherical the event, the lower the value of  $\mathcal{F}$ . We require  $\mathcal{F}$  to be smaller than a threshold which varies from 0.04 to 0.2 depending on the background level.

We extract the signal using the kinematic variables  $m_{\text{ES}} = \sqrt{E_b^{*2} - (\sum_i \mathbf{p}_i^*)^2}$  and  $\Delta E = \sum_i \sqrt{m_i^2 + \mathbf{p}_i^{*2}} - E_b^*$ , where  $E_b^*$  is the beam energy in the c.m. frame,  $\mathbf{p}_i^*$  is the c.m. momentum of daughter particle  $i$  of the  $B$  meson candidate, and  $m_i$  is the mass hypothesis for particle  $i$ . For signal events,  $m_{\text{ES}}$  peaks at the  $B$  meson mass with a resolution of about  $2.5 \text{ MeV}/c^2$  and  $\Delta E$  peaks near zero, indicating that the candidate system of particles has total energy consistent with the beam energy in the c.m. frame. The  $\Delta E$  signal band is defined by  $|\Delta E| < 36 \text{ MeV}$  and within it we define as signal candidates the events with  $m_{\text{ES}} > 5.27 \text{ GeV}/c^2$ .

After the aforementioned selection, three classes of backgrounds remain. First, the amount of *combinatorial background* in the signal region is estimated from the sidebands of the  $m_{\text{ES}}$  distribution and is described by a threshold function  $\frac{dN}{dx} = x \sqrt{1 - x^2/E_b^{*2}} \exp[-\xi(1 - x^2/E_b^{*2})]$ , characterized by the shape parameter  $\xi$  [15].

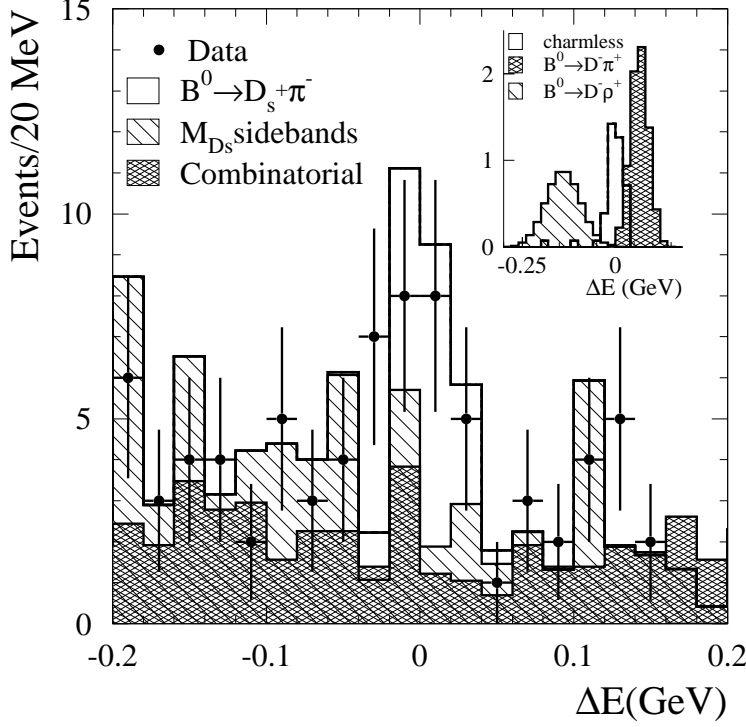


Figure 1: The  $\Delta E$  distribution in data compared with the distribution in the combinatorial background, estimated from the  $m_{\text{ES}}$  sidebands, and with the cross-contamination, which is estimated from the  $M_{D_s}^{\text{cand}}$  sidebands. The insert shows separately the  $\Delta E$  distribution of the contributions to the cross contamination as expected from the simulation. The reflection background is normalized to the known branching fractions [12], while the normalization of the charmless background is arbitrary.

Next,  $B$  meson decays such as  $\bar{B}^0 \rightarrow D^+ \pi^-, \rho^-$  with  $D^+ \rightarrow K_s^0 \pi^+$  or  $\bar{K}^{*0} \pi^+$  can constitute a background for the  $B^0 \rightarrow D_s^+ \pi^-$  mode if the pion in the  $D$  decay is misidentified as a kaon (*reflection background*). This background has the same  $m_{\text{ES}}$  distributions as the signal but different distributions of  $\Delta E$ . The corresponding background for the  $B^0 \rightarrow D_s^- K^+$  mode ( $B^0 \rightarrow D^- K^+, K^{*+}$ ) has a branching fraction ten times smaller. Finally, rare  $B$  decays into the same final state, such as  $B^0 \rightarrow \bar{K}^{(*)0} K^+ \pi^-$  or  $\bar{K}^{(*)0} K^+ K^-$  (*charmless background*), have the same  $m_{\text{ES}}$  and  $\Delta E$  distributions as the signal. Figure shows the  $\Delta E$  distribution for the signal and for the various sources of background.

The branching fraction of the charmless background is not well measured and we therefore need to estimate the sum of the reflection and charmless background (referred to as *cross-contamination*) directly on data. This is possible because both of these backgrounds have a flat distribution in the  $D_s^+$  candidate ( $M_{D_s}^{\text{cand}}$ ) mass while the signal has a Gaussian distribution. Possible peaking background from  $B \rightarrow D_s^+ X$  decays is negligible, as determined from simulation. The cross-contamination to the decays  $B^0 \rightarrow D_s^{*+} \pi^-$  and  $B^0 \rightarrow D_s^{*-} K^+$  is dominated by the reflection background which we estimate from simulation. Cross-feed between  $B^0 \rightarrow D_s^{(*)+} \pi^-$  and  $B^0 \rightarrow D_s^{(*)-} K^+$  modes has been estimated to be less than 1%.

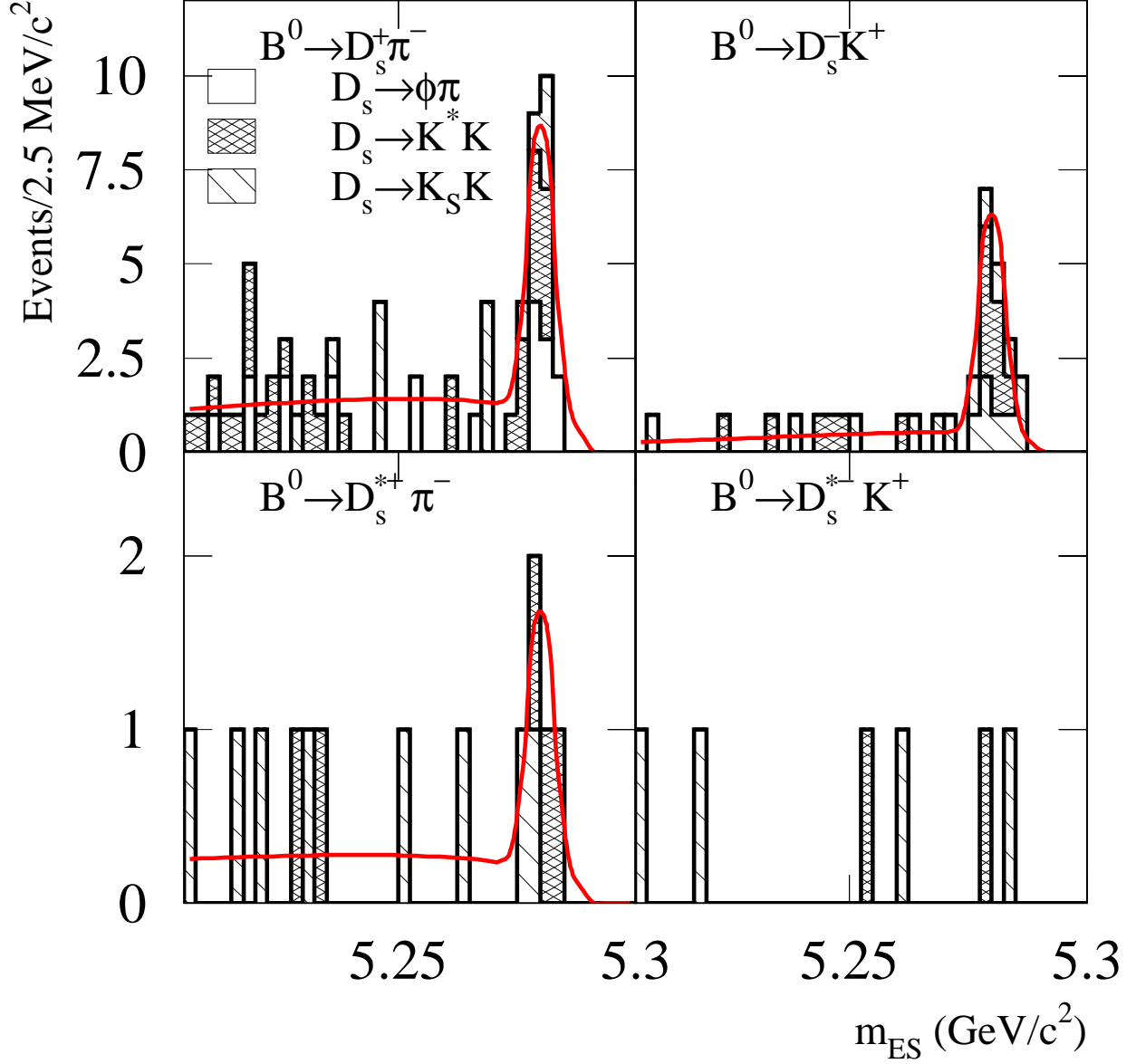


Figure 2: The  $m_{\text{ES}}$  distributions for the  $B^0 \rightarrow D_s^+ \pi^-$  (top left),  $B^0 \rightarrow D_s^{*+} \pi^-$  (top right),  $B^0 \rightarrow D_s^- K^+$  (bottom left), and  $B^0 \rightarrow D_s^{*-} K^+$  (bottom right) candidates on data after the selection, within the  $\Delta E$  band. The fits used to obtain the signal yield are described in the text. The contribution from each  $D_s^+$  mode is shown.

Figure shows the  $m_{\text{ES}}$  distribution for each of the modes in the  $\Delta E$  signal band. We perform an unbinned maximum-likelihood fit to each  $m_{\text{ES}}$  distribution with the threshold function to characterize the combinatorial background and a Gaussian function to describe the sum of the signal and cross-contamination contributions. The mean and the width of the Gaussian distribution are

Table 1: The number of signal candidates ( $N_{sigbox}$ ), the Gaussian yield ( $N_{gaus}$ ) and the combinatorial background ( $N_{comb}$ ) as extracted from the likelihood fit, the reconstruction efficiency ( $\varepsilon$ ), the cross-contamination ( $N_{cross}$ ), the probability ( $P_{bckg}$ ) of the data being consistent with the background fluctuating up to the level of the data in the absence of signal, the measured branching fraction ( $\mathcal{B}$ ), and the 90% confidence level upper limit.  $N_{gaus}$ ,  $N_{comb}$  and  $\mathcal{B}$  are not available for modes with too few events.  $N_{cross}$  is not reported if no event is found in the  $D_s^+$  mass sideband.

$B$ mode	$N_{sigbox}$	$N_{gaus}$	$N_{comb}$	$N_{cross}$	$\varepsilon(\%)$	$P_{bckg}$	$\mathcal{B}(10^{-5})$	90% C.L. ( $10^{-5}$ )
$B^0 \rightarrow D_s^+ \pi^-$								
$D_s^+ \rightarrow \phi \pi^+$	9	$8.0 \pm 3.0$	$2.1 \pm 0.7$	$< 0.7$	16.9	$1.4 \times 10^{-3}$	$3.1 \pm 1.2$	-
$D_s^+ \rightarrow \bar{K}^{*0} K^+$	12	$9.2 \pm 3.4$	$3.8 \pm 1.0$	$2.9 \pm 1.8$	9.6	$2.3 \times 10^{-2}$	$3.5 \pm 1.9$	-
$D_s^+ \rightarrow K_S^0 K^+$	5	$4.2 \pm 2.2$	$1.9 \pm 0.6$	$1.2 \pm 1.4$	12.3	$8.3 \times 10^{-2}$	$2.4 \pm 1.8$	-
all	26	$21.4 \pm 5.1$	$7.8 \pm 1.7$	$3.7 \pm 2.4$	N/A	$9.5 \times 10^{-4}$	$3.2 \pm 0.9 \pm 1.0$	-
$B^0 \rightarrow D_s^{*+} \pi^-$								
$D_s^+ \rightarrow \phi \pi^+$	2	-	$0.6 \pm 0.3$	$< 0.14$	7.8	-	-	-
$D_s^+ \rightarrow \bar{K}^{*0} K^+$	3	$2.8^{+2.7}_{-1.8}$	$0.4 \pm 0.3$	$0.3 \pm 0.2$	3.3	$3.9 \times 10^{-2}$	$4.3^{+4.7}_{-3.1}$	$< 12$
$D_s^+ \rightarrow K_S^0 K^+$	0	-	$0.4 \pm 0.3$	$< 0.14$	5.1	-	-	-
all	5	$4.4^{+2.7}_{-2.8}$	$1.2 \pm 0.4$	$0.3 \pm 0.2$	N/A	$2.3 \times 10^{-2}$	$1.9^{+1.2}_{-1.3} \pm 0.5$	$< 4.1$
$B^0 \rightarrow D_s^- K^+$								
$D_s^+ \rightarrow \phi \pi^+$	7	$5.8 \pm 2.6$	$1.3 \pm 0.7$	$1.1 \pm 1.2$	13.0	$4.5 \times 10^{-2}$	$2.4 \pm 1.3$	-
$D_s^+ \rightarrow \bar{K}^{*0} K^+$	8	$7.3 \pm 2.9$	$1.7 \pm 0.7$	$< 0.7$	7.8	$1.9 \times 10^{-3}$	$5.0 \pm 2.0$	-
$D_s^+ \rightarrow K_S^0 K^+$	4	$3.7 \pm 2.0$	$0.6 \pm 0.4$	$1.3 \pm 1.0$	9.2	$1.7 \times 10^{-2}$	$2.5 \pm 2.1$	-
all	19	$16.7 \pm 4.3$	$3.5 \pm 1.3$	$2.7 \pm 1.9$	N/A	$5.0 \times 10^{-4}$	$3.2 \pm 1.0 \pm 1.0$	-
$B^0 \rightarrow D_s^{*-} K^+$								
$D_s^+ \rightarrow \phi \pi^+$	0	-	$0.8 \pm 0.6$	$< 0.14$	5.3	-	-	-
$D_s^+ \rightarrow \bar{K}^{*0} K^+$	1	-	$0.4 \pm 0.4$	$< 0.14$	2.7	-	-	-
$D_s^+ \rightarrow K_S^0 K^+$	1	-	$0.4 \pm 0.4$	$< 0.14$	4.3	-	-	-
all	2	-	$1.6 \pm 0.8$	$< 0.14$	N/A	0.48	-	$< 2.5$

fixed to the values obtained in a copious  $B^0 \rightarrow D^{(*)-} \pi^+$  control sample. For the  $B^0 \rightarrow D_s^+ \pi^-$  and  $B^0 \rightarrow D_s^- K^+$  analyses, we obtain the threshold parameter  $\xi$  from a fit to the data distributions of  $m_{ES}$  after loosening the  $M_{D_s}^{cand}$  and  $\Delta E$  requirements. In the case of  $B^0 \rightarrow D_s^{*+} \pi^-$  and  $B^0 \rightarrow D_s^{*-} K^+$ , due to the low background level, we use simulated events to estimate  $\xi$ .

No fit is performed to the  $B^0 \rightarrow D_s^{*-} K^+$  sample, due to the low number of events. Whenever there are enough events we perform a fit to each  $D_s^+$  decay mode separately, as well as on the combination of all modes. The cross-contamination is estimated performing the same fit on the events in the data  $M_{D_s}^{cand}$  sidebands ( $4\sigma < |M_{D_s}^{cand} - 1968.6 \text{ MeV}/c^2| < 8\sigma$ , where the resolution is  $\sigma_{M_{D_s}^{cand}} = 5 \text{ MeV}/c^2$ ). The number of observed events, the background expectations and the reconstruction efficiencies as estimated on simulated events are summarized in Table 1.

In the  $B^0 \rightarrow D_s^+ \pi^-$  ( $B^0 \rightarrow D_s^- K^+$ ) mode the fit yields a Gaussian contribution of  $21.4 \pm 5.1$  ( $16.7 \pm 4.3$ ) events and a combinatorial background of  $7.8 \pm 1.7$  ( $3.5 \pm 1.3$ ) events. The cross-contamination is estimated to be  $3.7 \pm 2.4$  ( $2.7 \pm 1.9$ ) events. The probability of the background to fluctuate to the observed number of events, taking into account both Poisson fluctuations and uncertainties in the background estimates, is  $9.5 \times 10^{-4}$  ( $5.0 \times 10^{-4}$ ). For a Gaussian distribution this would correspond to  $3.3\sigma$  ( $3.5\sigma$ ). Given the estimated reconstruction efficiencies we measure  $\mathcal{B}(B^0 \rightarrow D_s^+ \pi^-) = (3.2 \pm 0.9) \times 10^{-5}$  ( $\mathcal{B}(B^0 \rightarrow D_s^- K^+) = (3.2 \pm 1.0) \times 10^{-5}$ ), where the quoted error is statistical only. We also set the 90% C.L. limits  $\mathcal{B}(B^0 \rightarrow D_s^{*+} \pi^-) < 4.1 \times 10^{-5}$  and  $\mathcal{B}(B^0 \rightarrow D_s^{*-} K^+) < 2.5 \times 10^{-5}$ . All results are preliminary.

The systematic errors are dominated by the 25% relative uncertainty in  $\mathcal{B}(D_s^+ \rightarrow \phi \pi^+)$ . The

uncertainties on the knowledge of the background come from uncertainties in the  $\xi$  parameter, for the combinatorial background, and from the limited number of events in the  $M_{D_s}^{cand}$  sidebands for the cross-contamination. They amount to 14%, 16%, 7% and 36% of the measured branching fractions in the  $B^0 \rightarrow D_s^+ \pi^-$ ,  $B^0 \rightarrow D_s^- K^+$ ,  $B^0 \rightarrow D_s^{*+} \pi^-$  and  $B^0 \rightarrow D_s^{*-} K^+$  modes respectively. The rest of the systematic errors, which include the uncertainty on tracking,  $K_s^0$  and charged kaons identification efficiencies range between 11% and 14% depending on the mode.

In conclusion, we report a  $3.3\sigma$  signal for the  $b \rightarrow u$  transition  $B^0 \rightarrow D_s^+ \pi^-$  and a  $3.5\sigma$  signal for the  $B^0 \rightarrow D_s^- K^+$  decay, and we determine the preliminary results

$$\begin{aligned}\mathcal{B}(B^0 \rightarrow D_s^+ \pi^-) &= (3.2 \pm 0.9 \text{ (stat.)} \pm 1.0 \text{ (syst.)}) \times 10^{-5} \\ \mathcal{B}(B^0 \rightarrow D_s^- K^+) &= (3.2 \pm 1.0 \text{ (stat.)} \pm 1.0 \text{ (syst.)}) \times 10^{-5}.\end{aligned}$$

Since the dominant uncertainty comes from the knowledge of the  $D_s^+$  branching fractions we also compute  $\mathcal{B}(B^0 \rightarrow D_s^+ \pi^-) \times \mathcal{B}(D_s^+ \rightarrow \phi \pi^+) = (1.13 \pm 0.33 \pm 0.21) \times 10^{-6}$  and  $\mathcal{B}(B^0 \rightarrow D_s^- K^+) \times \mathcal{B}(D_s^- \rightarrow \phi \pi^+) = (1.16 \pm 0.36 \pm 0.24) \times 10^{-6}$ . The search for  $B^0 \rightarrow D_s^{*+} \pi^-$  and  $B^0 \rightarrow D_s^{*-} K^+$  yields the preliminary 90% C.L. upper limits

$$\begin{aligned}\mathcal{B}(B^0 \rightarrow D_s^{*+} \pi^-) &< 4.1 \times 10^{-5} \\ \mathcal{B}(B^0 \rightarrow D_s^{*-} K^+) &< 2.5 \times 10^{-5}.\end{aligned}$$

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